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Sprinkle Lightly - Salt and Alternatives for Highway De-icing

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Abstract:

De-icing chemicals are normally used on our highways during the winter for the safe transport of goods and services. However the de-icing salts create problems in the environment, e.g., salt contamination of groundwater and damage to vegetation, in addition to causing corrosion to vehicles and highway appurtenances. While there are alternatives to salt, many of these are not as effective nor as economical.

There are various ways of reducing the effects of salt but many of these would affect the level of service of the highways. One alternative to salt which shows great promise is CMA, calcium magnesium acetate. Limited test results to date suggest that CMA is less polluting and less corrosive than salt. CMA is presently not produced commercially, but its cost is expected to be considerably higher than salt. However, use of CMA might be justified in environmentally sensitive areas if the cost of all damages resulting from the use of salt is taken into account.

Key Words: de-icing chemicals, corrosion, environmental impacts, salt contamination, winter maintenance

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TABLE OF CONTENTS

PAGE

1/ INTRODUCTION 1

2/ PROBLEMS ARISING FROM THE USE OF DE-ICING CHEMICALS 2

3/ MINIMIZING THE EFFECTS OF DE-ICING SALTS 5

4/ PAVEMENT DE-ICING CHEMICALS -- THE ALTERNATIVES 8

5/ SUMMARY OF MEASURES TAKEN TO DATE 9

REFERENCES 10

1/ INTRODUCTION

The use of de-icing chemicals on the highways and other roads during the winter is necessary to maintain the safe and rapid transport of goods and services. It is common practice throughout the snowbelt areas in North America and Europe. These chemicals can, however, damage the environment and increase the corrosion rate of metals in motor vehicles and roadside appurtenances. Therefore, it is of utmost importance that care be exercised in the use of these chemicals and that no more should be applied than is absolutely necessary to maintain the accepted level of service and minimize environmental impacts.

Sodium chloride and calcium chloride are the two most widely used de-icing chemicals. Calcium chloride is effective at lower temperatures than is sodium chloride, but it is considerably more expensive. Sodium chloride (common salt) is used almost exclusively in Ontario. Both of these chemicals have similar effects on the environment. The purpose of this report is to summarize the potential effects of salt on the environment and discuss mitigating measures which may be considered.

2/ PROBLEMS ARISING FROM THE USE OF DE-ICING CHEMICALS

In addition to the benefits of salt in facilitating the use of roads and increasing safety during the winter, there are some negative effects associated with its use. These are thoroughly discussed in papers by Murray and Ulrich [1], by Brenner and Moshman [2], and in an earlier paper by Schraufnagel [3]. The potential effects include: the danger of polluting underground aquifers with chloride ions and the resulting pollution of wells, the pollution of streams with damage to stream life, and damage to roadside vegetation.

In sensitive areas, de-icing salts (in the form of chlorides) may be able to leach through permeable sandy subsoils and infiltrate to shallow groundwater tables or aquifers [4]. Chlorides dissolve readily in water at the surface and travel without much hindrance through permeable soils and fissured or fractured bedrock. If private wells are located in close proximity to a highway, and at shallow depths or in these aquifers, there is an opportunity for them to become contaminated. Once this occurs, it becomes very difficult to eliminate the contamination. Instead, the annual addition of de-icing salts tends to increase the salt concentration of the groundwater. If it increases sufficiently, it may be necessary to relocate a well to another aquifer, generally at a greater depth.

If the subsoils are relatively impermeable, then much of the surface waters containing salts are carried through surface drainage to creeks streams and rivers in the area. With sufficient flow the salt concentration is diluted, and damage to aquatic life can be kept to a minimum. It is not practical at this time to attempt to treat salt runoff from a highway.

The open storage of sand-salt mixtures in stockpiles can create environmental problems due to salt leaching [5]. When the extent of this problem became known in the 1960's, a program of dome construction was initiated to reduce this occurrence.

Not all sand stockpiles are presently covered, but a program for further construction is established with priority given to site locations in more

sensitive areas. More recently, better housekeeping methods have been introduced in Ministry patrol yard operations to reduce the amount of salt affecting the environment. In sensitive areas, sand stockpiles have been sprayed with Curasol which forms an impermeable film to prevent leaching of the salt. While it is difficult to quantify the benefits, it is known that substantial reductions have been realized in the amount of salt introduced into the environment as a result of these mitigating measures.

Salt can affect the vegetation adjacent to the roads and highways. At present, grasses which are tolerant to salt are used. The damage to other roadside vegetation was studied by Fromm in 1967 [6], and later in 1971 [7]. In these papers, it was concluded that there was drift from the roadway on to the fruit trees in roadside orchards which was causing the desiccation of first year growth and the resultant death of twigs and buds. It was not determined if this problem was caused solely by road spray (salt solution) or if windblown or condensed automotive and diesel exhausts also contributed to the damage. Evidence pointed toward exhaust fumes as a cause and this was substantiated by statistical studies [7].

Recently, two fruit growers have sued the Ministry for damages to their peach and apple trees alleged to have been caused by road spray during the winter. A decision has been handed down by the court against the Ministry. This decision admits the Ministry must apply de-icing chemicals to the road to keep it in "good repair", but holds the Ministry responsible for creating a nuisance which has prevented the growers from enjoying their property to the full. No proportion of damages has been set and this judgement is under appeal.

De-icing salts which contain the chloride ion, e.g., calcium chloride and sodium chloride, are known to accelerate the corrosion rate of metals, and this applies to all vehicles using the roads. This effect was studied by Fromm in 1967 [8] in controlled experiments and under highway conditions in the Toronto, North Bay, Cochrane, Ottawa, and Chatham areas. Tests were also run on the roads in Halifax Nova Scotia, Fredericton New Brunswick, and in Edmonton Alberta. It was found that in the Toronto area, 50% of the corrosion occurring on autobody steel was

due to salt use during the winter months, and the remaining 50% was due to atmospheric moisture and air pollution during the rest of the year. Because of this latter cause, a small reduction in the amount of salt used would have negligible effect in reducing motor vehicle corrosion, especially since the design and methods of construction of modern cars makes them much more resistant to corrosion than vehicles were in 1967. It should also be noted that parking cars in heated garages and failure to wash the vehicles vastly increases the rate of corrosion.

De-icing salts also contribute to the corrosion of reinforcing steel in concrete bridge decks and substructures which would otherwise be protected by the alkaline environment in concrete [9]. A reduction of salt usage on the roads would have little effect since considerable quantities of salt are already absorbed in the older structures and new structures are provided with additional protection against corrosion damage.

Effective repair and rehabilitation techniques have been developed for older structures. These include patching, waterproofing and resurfacing bridge decks to buy an extension of their service life, and cathodic protection which prevents further corrosion. In new construction, additional lines of defense are being provided by epoxy coated reinforcing bars, waterproofing and improved joint and drainage details. Research and Development work is now concentrating on measures to protect the substructure of bridges below the deck.

3/ MINIMIZING THE EFFECTS OF DE-ICING SALTS

The effects of de-icing salts on the environment can be reduced either by reducing the amount of salts used or by using a chemical which has a less damaging effect on the environment.

One way of reducing the amount of salt used would be by lowering the level of service. This can be done by allowing more time to clear the roads for which bare pavement is specified. Ontario has one of the highest levels of service and if it were acceptable to the travelling public, then an increase in "centre bare" conditions, with a resulting decrease in "bare" pavement roads, would allow a reduction of salt use. Another method of reducing the amount of salt would be to change road clearing procedures. In many patrols, the current method of snow clearing is to get some salt down at the beginning of the storm, then to alternately plow and salt until the storm is over. If this were changed for short storms as follows -- allow more time to clear the road, apply a light salting at the beginning of the storm, "plow only" until the storm is over, than make a final clearing with salt -- this procedure would result in a reduction of salt used on Ontario roads. In storms of longer duration, it may be necessary to apply salt during the storm to prevent pavement icing. These procedures would cause a slight lowering of the level of service and would be less damaging to the environment but the question of acceptability, from a mobility and safety point of view, remains.

All salt spreading vehicles should be kept in good calibration so that they spread only the prescribed amount and don't overdose the road. The setting of the gate controlling the rate of application should be done only by fully trained personnel.

The Research and Development Division of the Ministry has been conducting research into winter maintenance since 1977 to investigate ways to reduce salt usage while maintaining the same level of service. This study is still in progress, and an interim report was issued by Fromm in 1983 [10]. One of the many facets of winter maintenance investigated was the use of sand-salt mixtures. This Ministry's policies for winter maintenance are clearly set out in Reference 11 for the use of sand (5% salt

added) and salt alone for different highway conditions.

A brief summary of the findings of this research to date is as follows:

- Plow and Sand Only -- This procedure was used for a very short time on one stretch of highway only, to see if such a system might be feasible. The road became covered with packed snow and the surface potholed. The experiment was stopped and salt applied to clear the road. This confirms similar experiences in other jurisdictions.

- Prewetted Salt -- A supplier claimed that if salt were prewetted with a 30% calcium chloride solution, the total amount of salt used could be reduced by 25%. This procedure was tested in two locations over two winters and then discontinued, as the road tended to ice over. The prewetted salt went to work and melted the snow but due to blowing snow and the dilution of the brine, the road froze over and more salt and sand had to be applied. This resulted in a hazardous situation. A recent study carried out by the Ministry indicates that this process is not practical nor cost-effective compared to the Ministry's current practices [12].

- Salt Spreading Rates -- The recommended spreading rate of 130 kg/km was compared to rates of 100 kg/km, 155 kg/km and 185 kg/km. It was found that 130 kg/km was a good average figure. In mild conditions and with heavy traffic, 100 kg/km was sufficient while in more severe conditions, greater quantities of salt were required. An equation was developed to help predict the amount of salt required for the existing conditions, but more variables must be added before it will work for most circumstances.

- Sand-Salt Mixtures -- Where mixtures of salt and sand containing 25% or more salt were used, it was found that in most cases a lesser quantity of salt alone would have done the job and fewer trucks would have been required. The cost of cleaning up the sand in the spring must also be considered. The use of 15% sand-salt mixtures is currently being compared to salt alone and the results of the study should be available in 1984.

- **Built-in Pavement De-icing Compound** -- A material, Verglimit, can be incorporated in the asphaltic concrete pavement wearing course. This material has been successful on some bridge decks in Ontario and Europe for preventing bridge deck icing which can occur in the late fall and early winter. Verglimit consists of small pieces of calcium chloride (caustic added) which are coated with polymerized linseed oil to render them relatively waterproof and these are incorporated throughout the surface course mix. As the pavement surface wears down, fresh particles of Verglimit are exposed, the linseed oil seal is broken, and the calcium chloride forms a small pocket of brine. This prevents ice from adhering to the deck. Passing traffic throws the thin film of ice to the side of the road.

  This system is expensive but seems effective and should last for several years. The Research and Development Branch is updating its records on experience with Verglimit and plans to issue a report on the long-term performance in 1984.

4/ PAVEMENT DE-ICING CHEMICALS -- THE ALTERNATIVES

In addition to sodium and calcium chlorides, many different chemicals for pavement de-icing have been studied over the years. A study by Forbes in California [13] lists many chemicals, and a study of different chemicals is given in Reference 14. Most of the compounds tested were chlorides, phosphates, nitrates, and some organic materials. These studies were largely concerned with finding de-icing chemicals which were noncorrosive to steel. In all cases, the chemicals studied were much more expensive than sodium chloride and were just as harmful to the environment. The only reasonably priced and readily available chemical found was urea. This chemical, although noncorrosive to steel, is ten times more expensive than salt and is not as effective for melting ice. Thus salt has continued to be the main chemical used to treat roads.

Recent studies sponsored by the Federal Highway Administration (FHWA) have identified calcium magnesium acetate as one of the best alternatives to chlorides as a melting agent for highway use [15]. This de-icer can be made by reacting acetic acid with dolomitic lime to form a mixture of calcium and magnesium acetate known as CMA.

Research to date shows that CMA has the potential to reduce pollution and substantially decrease corrosion associated with salt de-icing. However, considerable research still has to be completed to determine the long term effects of CMA on vegetation, aquatic life, motor vehicles and the highway infrastructure.

To date, there are no commercial sources of CMA. The estimated cost of using CMA instead of salt to achieve "bare" pavement is approximately 14 to 30 times greater. It is believed, however, that with FHWA funded research and the application of modern technology, the manufacturing problems can be resolved.

If the technical promise of CMA is proven, then the extent of its use will be a matter of economics. The cost of CMA would seem to limit its use to environmentally sensitive areas. If, however, the cost of all damages associated with salt use is taken into account, then CMA might find even greater use. The Ministry is planning a study to try to answer this intriguing question.

5/ SUMMARY OF MEASURES TAKEN TO DATE

The following changes have been implemented by the Ministry to reduce salt usage and/or contamination:

- All salt is stored under cover (salt sheds);
- Sand-salt stockpiles in sensitive areas are treated with Curasol if not under a dome;
- Operating instructions and standard application rates have been developed;
- Training programs for MTC staff have been implemented;
- Electronic controls were installed on sanders to meter application rates;
- All salt use is recorded;
- Salt use is confined to those periods when temperature is in the range in which it is effective; and
- Salt use is confined to those highways with more than 500 vehicles per day in Southern Ontario and 400 vehicles per day in Northern Ontario.

The following items are the subject of continuing R & D:

- methods of detecting damage to structures;
- repair and rehabilitation measures for concrete structures;
- detection of deterioration and repair of weathering steel structures;
- general corrosion research, including cathodic protection;
- means of protecting fruit trees;
- optimum application of salt;
- prevention of snow drifting and whiteouts; and
- effects and economics of using alternative de-icing chemicals.

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